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Atlanto-occipital dislocation: four case reports of survival in adults and review of the literature

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Abstract Traumatic atlanto-occipital dislocation (AOD) is a rare cervical spine injury and in most cases fatal. Consequently, relatively few case reports of adult patients surviving this injury appeared in the literature. We retrospectively report four patients who survived AOD injury and were treated at our institution. A young man fell from height and a woman was injured in a traffic accident. Both patients survived the injury but died later in the hospital. The third patient had a motorcycle accident and survived with incomplete paraplegia. The last patient, a man involved in a working accident, survived without neurological deficit

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Keywords Atlanto-occipital dislocation · Cervical spine injury · Posterior cervical fusion

Introduction

Fractures and dislocations of the cranio-cervical junction represent one-third of all injuries to the cervical spine. They are usually caused by high-energy trauma such as traffic accident or fall from a great height [3, 9]. Atlanto-occipital dislocation (AOD), because of its accompanying injuries to the brain stem and lesions to the vascular structures of the neck, is mostly a lethal injury [11, 32, 98]. The diagnosis is often overlooked [74]. Recognition of AOD and therapeutic procedures are hampered by the frequent combination of AOD with traumatic brain injury and/or polytrauma. In this article four adult patients with AOD are presented and two showed a long-term survival and were surgically treated.

Case reports

Case 1

A 22-year-old man fell 12 m from a roof, was unconscious and had a Glasgow Coma Scale (GCS) of three points for an unknown time. Cardiac arrest and apnea occurred after arrival of the rescue team. Following successful resuscitation and intubation, the patient was transferred to the emergency ward of the University Hospital of Zurich without relaxation or sedation. The GCS was unchanged, pupillary light reactions and vital signs were normal. Except for a generalized brain edema in the computed tomography (CT) scan of the head, there were no pathological findings in the clinical and radiological work-up. After insertion of a subdural catheter for intracranial pressure (ICP) monitoring, the patient was transferred to the intensive care unit (ICU). On the first posttraumatic day, clinical neurological examination showed bilateral cranial

nerve palsies, absent gag reflex and flabby tetraparesis. Electroencephalogram (EEG) showed a suppression burst pattern and there were no reactions in somatosensory evoked potentials, which was consistent with a high spinal paralysis. Intracranial pressure remained normal all the time. Control CT scan of the head showed a decreased cerebral edema without intracerebral ischaemia or concussions. After an attempt of a wake up, the patient showed a hypoxic aphalic syndrome suspicious of a high cervical spine lesion. Magnetic resonance imaging (MRI) confirmed the diagnosis of an AOD with traumatic lesions of the upper cervical spinal cord and of the lower brain stem. The patient died on tenth day due to severe lesion in the transition from medulla oblongata to spinal cord, verified by autopsy as a severe myelomalacia (total necrosis) in the described anatomic region.

Case 2

A 68-year-old woman was hit by a tram. On arrival of the rescue team, the patient showed a gasping breathing and a GCS of three points with no pupillary light reaction on the left eye. In the emergency ward of our hospital, the patient was orally intubated, sedated, relaxed and developed a

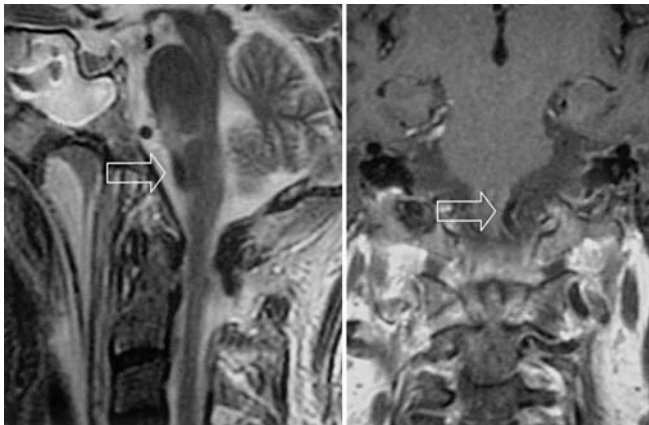
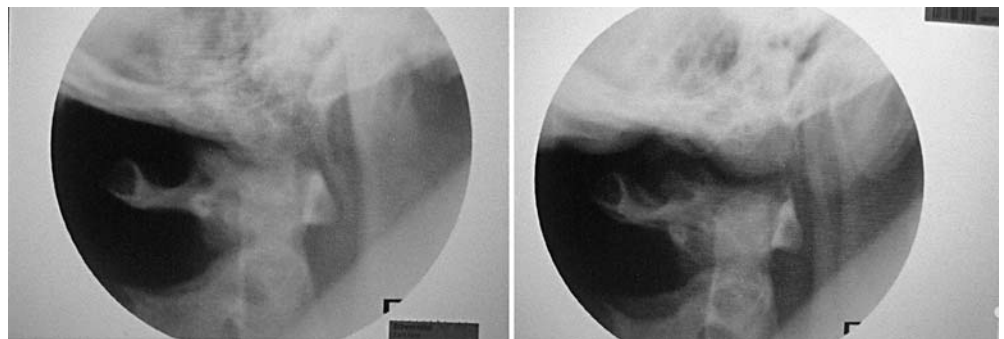


Fig. 1 Sagittal and frontal T2-weighted MRI sequences. Lesion in the pontomedullary junction (arrows)

Fig. 2 Functional examination under image intensifier demonstrating atlanto-occipital dislocation (AOD)

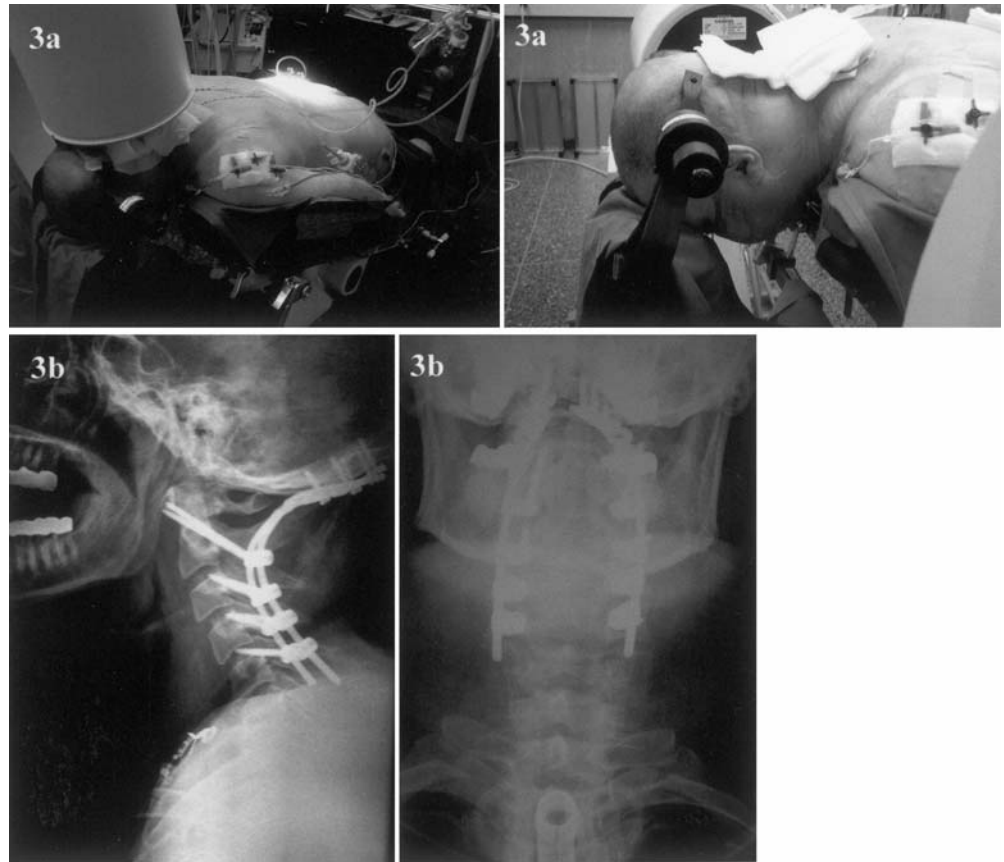


haemodynamic instability. After cardiopulmonary resuscitation, clinical and radiological work-up revealed AOD together with a traumatic brain injury and subarachnoidal bleeding. Furthermore, a chest trauma with serial rib fractures, lung contusions on both sides, a pelvic fracture, a floating elbow with an open distal fracture of the humerus, a closed forearm fracture and a fracture of right radius were diagnosed. After immediate insertion of chest tubes, a subdural catheter was placed for ICP monitoring and the left fractured humerus was stabilized by an external fixator. The patient was then transferred to the ICU, where she died the same day due to severe brain and thoracic injuries.

Case 3

A 51-year-old man fell from a motorcycle and collided with a crash barrier. The patient was resuscitated by paramedics until the ambulance arrived. He was orally intubated at the scene showing a GCS of 3 points and no pupillary light reaction on the left eye. Clinical and radiological assessment by conventional X-ray and CT scan of the head revealed a severe brain injury with haemorrhagic concussions on the left temporal side, multiple subarachnoidal haemorrhages, further “shearing injuries” and a ligamentous instability of the right elbow and knee. The CT scan did not show any signs of injuries in the occipito-cervical junction. The ratio according to Powers et al. [73] was less than 0.9. A ventricular catheter for ICP monitoring was inserted and the patient was transferred to ICU. Despite a constantly low intracranial pressure, a failing attempt to wake the patient was a sign of a lesion in the pontomedullary junction. An MRI scan confirmed the diagnosis of an ischaemic lesion in this region (Fig. 1). The injury pattern, the incomplete flabby tetraplegia, the presence of a “locked in” syndrome, bilateral palsy of the *N. abducens* and absent gag reflex indicated AOD. An examination under the image intensifier confirmed the diagnosis (Fig. 2). The neurological findings did not change during hospitalisation. The AOD was stabilized by a dorsal fusion between the occiput and C5 by Cervifix (Stratec, Oberdorf, Switzerland; Fig. 3). Due to patient’s neurologene dysphagia, tracheotomy and endoscopically assisted

Fig. 3 **a** Positioning of the patient, in prone position, with fixation of the head by a May-field clamp. **b** Postoperative X-rays showing stabilization of the AOD by dorsal fusion, from the occiput to C5, with Cervifix and cancellous bone



percutaneous gastroenterostomy (PEG) were performed. Postoperative complications were not observed. Early physiotherapy was applied according to the Bobath scheme. The patient was transferred to other hospital for further neuro-rehabilitation where he progressively recovered from his neurological deficits. Sixteen months after the accident, he was fully ambulatory without medical aids. The patient, besides an incomplete paraplegia, has a persistent hoarseness and a bilateral palsy of the abducens nerve, for which he has undergone an operative correction.

Case 4

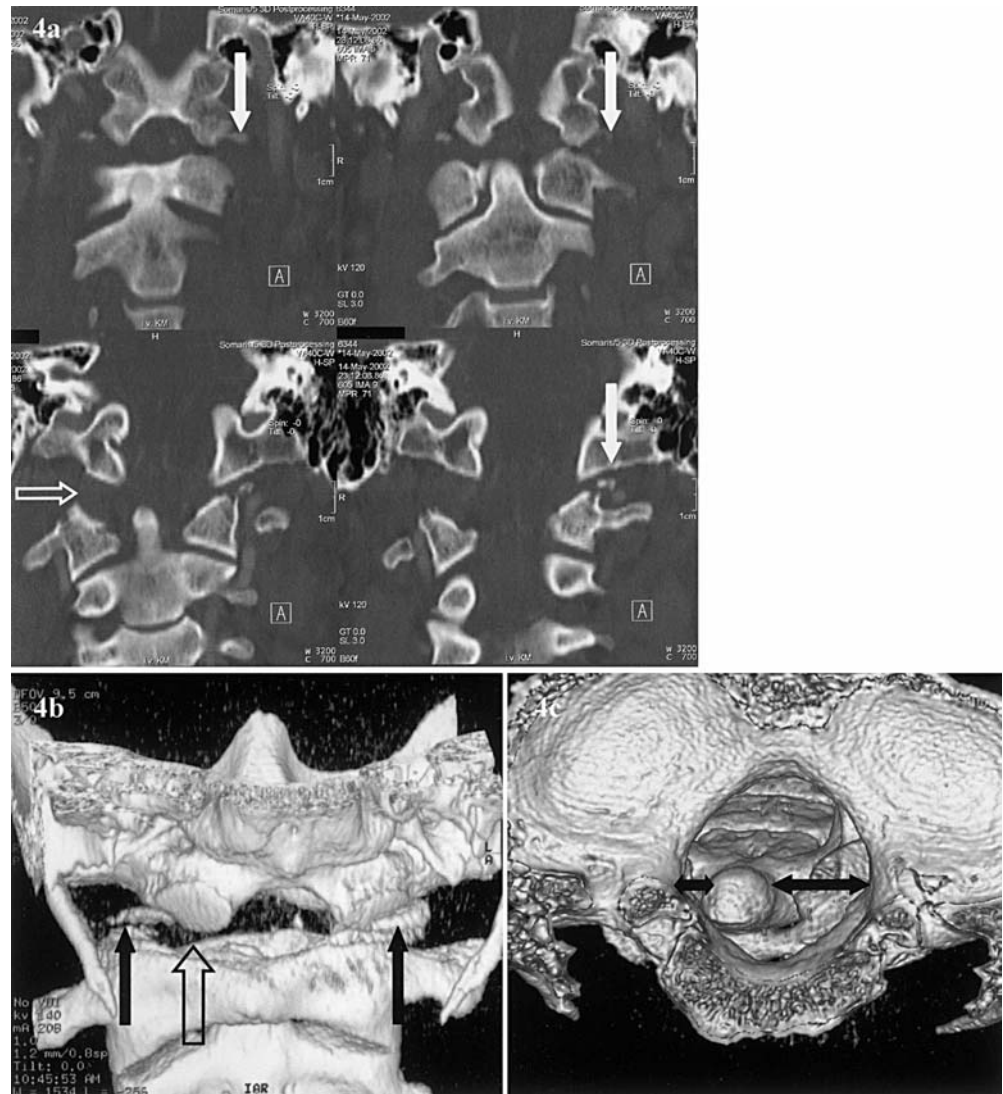
A 35-year-old patient tipped over with a forklift and his shoulder was wedged in by the roof of the engine. At the scene, the initial GCS was 15 points and the patient was able to move his extremities with exception of the right arm. Because of increasing shortness of breath and an inspiratory stridor, he was intubated at the scene by the rescue ambulance and transferred to the University Hospital of Zurich. Clinical work-up revealed a massive swelling at the neck, a subtotal tear of the auricle and a cut at the forearm. Radiological examinations showed fractures of the right clavicle, the left scapula and gave a hint on an injury in the occipito-cervical junction (Fig. 4). The ratio ac-

cording to Powers et al. [73] was 1.1. The diagnosis of AOD was confirmed by functional X-rays (Fig. 5). During the wake-up, bilateral sensomotor deficiency with palsies of shoulder girdle and the upper extremities were observed. An MRI scan showed a lesion of the vertebral artery and the presence of an epidural haematoma (Fig. 6). The AOD was then stabilised by a dorsal fusion of C0–C5 with a Cervifix (Fig. 7). Postoperative complications were not observed and the neurological deficits of the upper extremities receded. The patient was transferred for further neuro-rehabilitation. Three months after the accident, the patient was fully ambulatory without aids. He still complains of a persistent sensomotor shortage of the right arm at C4–C6. The patient was discharged for ambulatory treatment.

Discussion

A recent study reports an incidence of cervical injuries of 4.3% [39]. The incidence of cervical spine injuries following blunt trauma in children is estimated to be 1.3–1.5% [71, 72]. In 30% of 300 analysed patients with cervical spine injuries the localisation is in the upper region, i.e. between C0 and C2 [9]. Radiological injuries of the upper cervical spine, of which 93% were in the first two

Fig. 4 **a** Atlanto-occipital dissociation in the CT scan demonstrating the subluxation with a rotationalary component after first reduction (*open arrow*) and avulsion fracture of the ligaments (*solid arrows*). **b** A 3D reconstruction with an anteroposterior view (*arrows*). **c** Subluxation viewed cranially through the foramen magnum (*arrows*)



segments, were found in 24.4% of 312 deceased traffic victims [3]. Solely ligamentous injuries to the cervical spine were found in only 14 patients of 14,577 with blunt trauma [16]. Injuries to the upper cervical spine are frequent in traffic accidents with the highest prevalence for pedestrians and motorcyclists [86].

Atlanto-occipital dislocation, described for the first time by Blackwood in 1908, is a rare injury [8]. Among 155 examined traffic victims, 12 patients with AOD were found with additional various fractures in the occipito-cervical junction [1]. Others report an incidence of AOD of 8% up to 31% in fatal traffic accidents [11, 98] and of nearly 10% in fatal cervical spine injuries [3]. The AOD may be complete or incomplete. Three different types (ventral, dorsal, axial) of complete AOD were described [88]. The ventral dislocation (type I) is the most common case, the axial dislocation (type II) the most unstable one and the dorsal dislocation (type III) the rarest [42]. In our four cases we found two of type-I (cases 2 and 4) and two

of type-II (cases 1 and 3) dislocations. Additionally, lateral dislocations of AOD have been described [90]. Incomplete forms of AOD represent subluxations of the atlanto-occipital junction [42]. The atlanto-occipital, the lateral atlanto-axial and the median atlanto-axial articulations are a functional unit. The overall effect of all joints equals a spherical joint. The rigidity depends mostly on the surrounding ligamentous structures. Among these, the membrana tectoria and the bilateral ligamenta alaria are the main stabilizer [92]. Children and young adults suffer more AOD [11, 24, 64, 79], because of a disparity between the occipital condyles and the articular surfaces of the atlas, a more horizontal plane of the articular surfaces and an increased laxity of the ligamentous structures [12, 45, 52, 80]. Additionally, there are reports that airbag deployment may cause AOD in children [4, 35, 36].

Neurological deficits in up to 33% [32] and vascular complications lead to high mortality. The immediate cause of death may be due to vascular lesions to carotid arteries

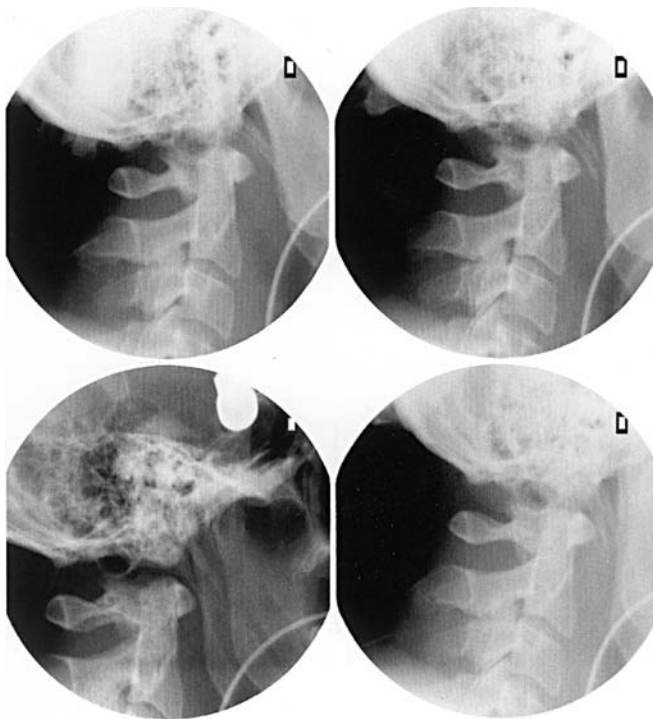


Fig. 5 Functional tests of the atlanto-occipital junction under image intensifier

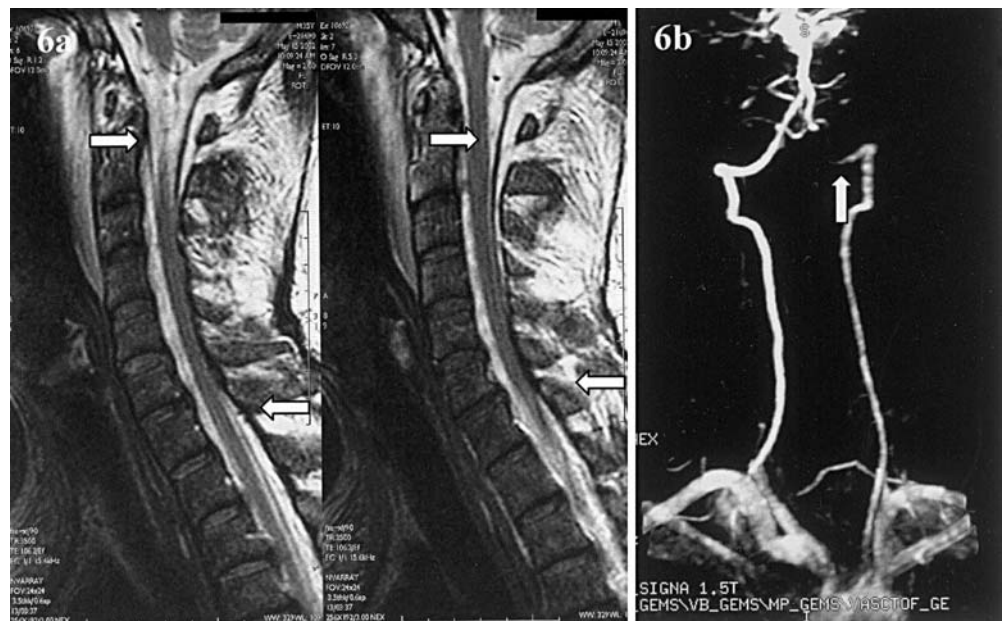
or vertebral arteries [25, 27, 33, 58, 68, 73] as well as to direct injury to the spinal cord or brain stem [11, 25, 52]. Our patient in case report 4 showed a lack of a vertebral artery due to AOD. Three of our four patients showed signs of direct injuries of the spinal cord or the brain stem. Subdural haematoma as accompanying injury of AOD is

described in 16% of cases [1]. A combination with aortic lesions is reported in 25% and with basal skull fractures in 21% [86]. Except our case 4, all patients suffered from severe head injuries. Injuries to the brain nerves, particularly the abducens nerve (N VI) as for example, in our case 4, are occasionally reported in the literature [15, 27, 31, 33]. Out of a group of eight patients with AOD, one patient sustained a rupture of the membrana tectoria with a lethal outcome, and in the remaining seven cases, MRI showed a characteristic stretching with a simultaneous elevation from the clivus and the tip of the dens and a fluid collection [84]. Fourteen of the 79 surviving (18%) patients showed no neurological deficits, and 8 (10%) showed isolated deficits of brain nerves [74].

Absence of neurological deficits has also been reported by other authors [26, 29, 31, 33, 52, 66]. Hemiplegia occurred in 34% and tetraplegia in 38% in patients surviving AOD [74]. Patients with AOD have been reported to show an improvement of neurological deficits [22, 27, 31, 33, 38, 41, 51, 52, 54, 56, 58, 66, 85, 91, 93] and this was also the case with our two patients with long-term survival who both showed an improvement of neurological deficits. Rupture of the trachea [67] and retropharyngeal pseudomeningocele [63] were reported as rare complications following AOD.

The majority of patients with an AOD are either immediately dead or survive for few hours only [3, 9, 11]; therefore, this injury was considered potentially lethal [26, 27, 29, 31, 33, 66, 73, 77]. Due to improved pre-hospital care, rapid rescue and shorter transportation time, the number of patients surviving AOD and arriving alive in the hospital is increasing [2, 4, 6, 7, 10, 12, 13, 15, 17, 18, 19, 20, 22, 23, 24, 25, 28, 30, 34, 35, 38, 40, 41, 43, 44, 45, 46, 47, 49, 50, 52, 54, 55, 56, 57, 58, 60, 61, 62, 63,

Fig. 6 **a** An MRI scan of AOD shows an epidural haematoma (*arrows*) with **b** associated lesion of the left vertebral artery (*arrow*)



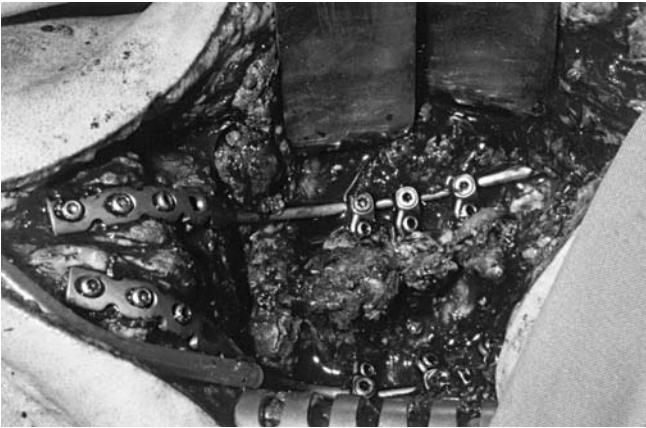


Fig. 7 Dorsal fusion from the occiput to C5 by Cervifix

Table 1 Literature review of adult patients surviving atlanto-occipital dislocation

No. of patients	Reference	No. of cases
1	[3, 5, 6, 7, 8, 9, 14, 19, 26, 33, 40, 43, 47, 48, 49, 50, 51, 55, 62, 63, 66, 67, 73, 76, 78, 79, 85, 87, 90, 91, 93, 95]	32
2–5	2, 10, 15, 25, 30, 74	17
>5	23]	7
Total		56

64, 65, 67, 69, 70, 71, 75, 76, 78, 79, 80, 81, 82, 83, 84, 85, 87, 89, 90, 91, 93, 94, 95, 96]. Meta-analysis of the literature between 1948 and present showed 211 patients surviving AOD including 131 (62%) children [2, 4, 9, 12, 13, 15, 17, 18, 20, 22, 23, 24, 25, 27, 28, 29, 30, 31, 34, 35, 38, 41, 44, 45, 46, 47, 52, 54, 56, 60, 61, 62, 64, 65, 68, 69, 71, 73, 74, 75, 77, 78, 79, 80, 81, 82, 83, 84, 88, 89, 93, 94, 96, 97] and 56 (27%) adults (Table 1). For the remaining 24 (11%) cases, the age of the patients was not specified [32, 37, 57].

A complete AOD is accompanied by massive swelling of the head and neck, and radiological diagnosis is, as in our fourth case, usually undemanding. In the presence of a respiratory insufficiency, an irregular cardiac activity up to a cardiac arrest or a hypotension, caused by traumatic lesions of the brain stem, AOD should be suspected [2]. Less prominent dislocations or spontaneously reduced AOD are easily overlooked despite the comprehensive radiological work-up [18, 22, 25, 30, 37, 45, 54, 56]. An analysis of 79 patients with AOD found that in 19 of 50 (38%) children and in 17 of 29 (59%) adults, the diagnosis of an AOD, particularly of an axial dislocation, was missed [74]. We too encountered the same problem in two of our four cases. Diagnostic work-up for AOD consists of a lateral view of the upper cervical spine and the assessment of the ratio according to Powers et al. [73], Har-

ris et al. [42], Dublin et al. [25] or Kaufmann et al. [53]. Functional examination under image intensifier is described [51], combined, if necessary, with monitoring of the somato-sensory potentials [5]. Computer tomography with sagittal, coronary, and three-dimensional reconstruction [21, 40, 60], MRI [13, 14, 21, 37] and angiography [58] are the instruments for the diagnosis and for the assessment of additional injuries in AOD. Avulsion fractures from the occipital condyles or the tip of the dens and a retropharyngeal haematoma may lead to the diagnosis of an AOD [21]. In the CT scan and the MRI in three of our four cases, we found the described radiological signs. Early diagnosis of AOD is mandatory to prevent further impairment of the spinal cord by manipulations during positioning, diagnostic work-up or therapeutic procedures.

After establishing vital functions, particularly of the airways, reposition and splinting are achieved by either a stiff neck, traction in a Gardner–Wells, or a Halo-fixator [7, 27, 29, 33, 56, 62, 67]. For axial dislocation of AOD (type II) traction is not recommended and should be avoided [52]. Complete retention is sometimes impossible due to interposition of fragments or ligamentous structures. Conservative treatment with extension or halo-fixator as further management is recommended in children and in the case of little instability of AOD [2, 28, 49, 56, 63, 73, 83, 84, 93]; however, from the aforementioned literature it is not evident how much instability may be tolerated. In children, a fibrous ankylosis is expected after months of conservative treatment [49, 56, 83, 93]. In adults and with increasing instability, a short dorsal spondylosis should be performed [15, 34, 68, 82, 93]. The dorsal fusion is achieved by an occipito-cervical tension wire band and augmentation by autologous cancellous bone with an immobilisation in a minerva cast [5, 15, 85]. Fusion by a bone graft from the iliac crest with additional plate fixation (Y-plate, Roy-Camille plate, reconstruction plate) and transpedicular screws allows early mobilization without a cast or with a soft neck for 6 weeks to 4 months [7, 18, 22, 27, 31, 46, 47, 68, 69, 78, 88, 93, 97]. A new technique for stabilization of AOD was described using transarticular fixation with additional occipito-cervical Y-plate fixation [38]. Fusion with the Cervifix system with a bone graft from the iliac crest with or without cancellous bone is an alternative dorsal stabilization procedure [51, 55] and was also applied in two of our four patients. The implant is made from titanium allowing post-operative CT scans with fewer artefacts. The implant design consists of a reconstruction plate in the cranial part and a rod system in the caudal part. An implant removal is not advisable even after complete neurological remission, because mobility from C0 to C2 is lost because of the bony consolidation.

Conclusion

It can be concluded that, due to improved rescue services, decreased transportation time, and increased awareness of the injury, the number of patients surviving AOD increases and that therefore longtime observations are possible [59, 69, 88]. Reviewing the literature, there are 211 documented patients surviving AOD initially and 108 (51%) cases, mainly children and young adults, showed a long-term survival. Diagnosis may be hampered and is frequently delayed, in part due the lack of clinical or ra-

diological evidence, in part due to the additional injuries where a clinical examination is impossible. The extent of neurological deficits in AOD varies from no deficits up to severe neurological deficits caused either by brain stem or spinal cord injuries and by vascular injuries (carotid and vertebral arteries). The therapeutic options range from conservative measures, usually in children, to operative fusion of the cervical spine. The prognosis of primary neurological deficits remains unfavourable; however, there are sporadic reports of neurological improvements after AOD [22, 27, 31, 33, 38, 41, 51, 52, 54, 56, 58, 66, 85, 91, 93].

References

- Adams VI (1992) Neck injuries: Part I. Occipitoatlantal dislocation – a pathologic study of twelve traffic fatalities. *J Forensic Sci* 37:556–564
- Ahuja A, Glasauer FE, Alker GJ Jr, Klein DM (1994) Radiology in survivors of traumatic atlanto-occipital dislocation. *Surg Neurol* 41:112–118
- Alker GJ Jr, Oh YS, Leslie EV (1978) High cervical spine and craniocervical junction injuries in fatal traffic accidents: a radiological study. *Orthop Clin North Am* 9:1003–1010
- Angel CA, Ehlers RA (2001) Images in clinical medicine. Atlanto-occipital dislocation in a small child after airbag deployment. *N Engl J Med* 345:1256
- Babbitt JD, Kim KD (2001) Unknown case. *Spine* 26:1401–1403
- Banna M, Stevenson GW, Tumiel A (1983) Unilateral atlanto-occipital dislocation complicating an anomaly of the atlas: a case report. *J Bone Joint Surg Am* 65:685–687
- Belzberg AJ, Tranmer BI (1991) Stabilisation of traumatic atlanto-occipital dislocation: case report. *J Neurosurg* 75:478–482
- Blackwood NJ (1908) Atlanto-occipital dislocation: a case of fracture of the atlas and axis, and forward dislocation of the occiput on the spinal column, life being maintained for thirty-four hours and forty minutes by artificial respiration, during which a laminectomy was performed upon the third cervical vertebra. *Ann Surg* 47:654–658
- Bohlmann HH (1979) Acute fractures and dislocations of the cervical spine: an analysis of three hundred hospitalized patients and review of the literature. *J Bone Joint Surg Am* 61:1119–1142
- Bools JC, Rose BS (1986) Traumatic atlantooccipital dislocation: two cases with survival. *AJNR* 7:901–904
- Bucholz RW, Burkhead WZ (1979) The pathological anatomy of fatal atlanto-occipital dislocations. *J Bone Joint Surg Am* 61:248–250
- Bulas DI, Fitz CR, Johnson DL (1993) Traumatic atlanto-occipital dislocation in children. *Radiology* 188:155–158
- Bundschuh CV, Alley JB, Ross M, Porter IS, Gudeman SK (1992) Magnetic resonance imaging of suspected atlanto-occipital dislocation: two case reports. *Spine* 17:245–248
- Chaljub G, Singh H, Gunito FC Jr, Crow WN (2001) Traumatic atlanto-occipital dislocation: MRI and CT. *Neuroradiology* 43:41–44
- Chattar-Cora D, Valenziano CP (2000) Atlanto-occipital dislocation: a report of three patients and a review. *J Orthop Trauma* 14:370–375
- Chiu WC, Haan JM, Cushing BM, Kramer ME, Scalea TM (2001) Ligamentous injuries of cervical spine in unreliable blunt trauma patients: incidence, evaluation, and outcome. *J Trauma* 50:457–464
- Cohen A, Hirsch M, Katz M, Sofer S (1991) Traumatic atlanto-occipital dislocation in children: review and report of five cases. *Pediatr Emerg Care* 7: 24–27
- Collato PM, Demuth WW, Schwenker EP, Boal DK (1986) Traumatic atlanto-occipital dislocation. *J Bone Joint Surg Am* 68:1106–1109
- Colnet G, Chabannes J, Commun C, Rigal MC, Alassaf M (1989) Luxation occipito-atloïdienne et syringomyelie deux complications rares de la traumatologie cervicale. Incidences diagnostiques et thérapeutiques. A propos d'un cas. *Neurochirurgie* 35:58–63
- Dallek M, Meenen NM, Jungbluth KH, Bentele KH, Grzyska U (1995) Traumatic dislocations of cranial spine in childhood: clinical description of 2 cases. *Unfallchirurgie* 21:40–44
- Deliganis AV, Baxter AB, Hanson JA, Fisher DJ, Cohen WA, Wilson AJ, Mann FA (2000) Radiologic spectrum of craniocervical distraction injuries. *Radiographics* 20:237–250
- DiBenedetto T, Lee CK (1990) Traumatic atlanto-occipital instability: a case report with follow-up and a new diagnostic technique. *Spine* 15:595–597
- Dickmann CA, Papadopoulos SM, Sonntag VKH, Spetzler RF, Rekeate HL, Drabier J (1993) Traumatic occipitoatlantal dislocation. *J Spinal Disord* 6:300–313
- Donahue DJ, Muhlbaier MS, Kaufmann RA, Warner WC, Sanford RA (1987) Childhood survival of atlanto-occipital dislocation: underdiagnosis, recognition, treatment, and review of the literature. *Pediatr Neurosurg* 21: 105–111
- Dublin AB, Marks WM, Weinstock D, Newton TH (1980) Traumatic dislocation of the atlanto-occipital articulation (AOA) with short-term survival. With a radiographic method of measuring AOA. *J Neurosurg* 52:541–546
- Eismont FJ, Bohlmann HH (1978) Posterior atlanto-occipital dislocation with fractures of the atlas and odontoid process: report of a case with survival. *J Bone Joint Surg Am* 60:397–399
- Evarts CM (1970) Traumatic occipitoatlantal dislocation: report of a case with survival. *J Bone Joint Surg Am* 52:1653–1660
- Farley FA, Graziano GP, Hensinger RN (1992) Traumatic atlanto-occipital dislocation in a child. *Spine* 17:1539–1541
- Farthing JW (1948) Atlantocranial dislocation with survival: a case report. *NC Med J* 9:34–36
- Ferrera PC, Bartfield JM (1996) Traumatic atlanto-occipital dislocation: a potentially survivable injury. *Am J Emerg Med* 14:291–296
- Fruin AH, Pirotte TP (1977) Traumatic atlanto-occipital dislocation: case report. *J Neurosurg* 46:663–666

32. Fujimura Y, Nishi Y, Chiba K, Kobayashi K (1995) Prognosis of neurological deficits associated with upper cervical spine injuries. *Paraplegia* 33:195–202
33. Gabrielsen TO, Maxwell JA (1966) Traumatic atlanto-occipital dislocation with case report of a patient who survived. *AJR* 97:624–629
34. Georgopoulos G, Pizzutillo PD, Soo Lee M (1987) Occipito-atlantal instability in children. *J Bone Joint Surg Am* 69:429–436
35. Giguere JF, St. Vil D, Turmel A, Lorenzo M di, Pothel C, Manseau S, Mercier C (1998) Airbags and children: a spectrum of C-spine injuries. *J Pediatr Surg* 33:811–816
36. Gossman W, June RA, Wallace D (1999) Fatal atlanto-occipital dislocation secondary to airbag deployment. *Am J Emerg Med* 17:741–742
37. Grabb BC, Frye TA, Hedlund GL, Vaid YN, Grabb PA, Royal SA (1999) MRI diagnosis of suspected atlanto-occipital dissociation in childhood. *Pediatr Radiol* 29:275–281
38. Grob D (2001) Transarticular screw fixation for atlanto-occipital dislocation. *Spine* 26:703–707
39. Grossman MD, Reilly PM, Gillett T, Gillett D (1999) National survey of incidence of cervical spine injury and approach to cervical spine clearance in U.S. trauma centers. *J Trauma* 47: 684–690
40. Guigui P, Milaire M, Morvan G, Lasale B, Deburge A (1995) Traumatic atlanto-occipital dislocation with survival: case report and review of the literature. *Eur Spine J* 4:242–247
41. Harmanli O, Koyfman Y (1993) Traumatic atlanto-occipital dislocation with survival: a case report and review of the literature. *Surg Neurol* 39:324–330
42. Harris JH, Carson GC, Wagner LK, Kerr N (1994) Radiologic diagnosis of traumatic occipitovertebral dislocation: comparison of three methods of detecting occipitovertebral relationships on lateral radiographs of spine subjects. *AJR* 162:887–892
43. Henry MB, Angelastro DB, Gillen JP (1998) Unrecognized traumatic atlanto-occipital dislocation. *Am J Emerg Med* 16:406–408
44. Hladky JP, Lejeune JP, Leclercq F, Dhellemmes P, Christiaens JL (1991) La dislocation occipito-atloïdienne traumatique. *Neurochirurgie* 37:312–317
45. Hosono N, Yonenobu K, Kawagoe K, Hirayama N, Ono K (1993) Traumatic anterior atlanto-occipital dislocation: a case report with survival. *Spine* 18: 786–790
46. Houle P, McDonnell DE, Vender J (2001) Traumatic atlanto-occipital dislocation in children. *Pediatr Neurosurg* 34:193–197
47. Hummel A, Plau R (1988) Diagnostik und Behandlung atlanto-occipitaler Rupturen. *Unfallchirurgie* 14:311–319
48. Isaef SA, Siegel A (2000) Brain scintigraphy of cerebellar infarction secondary to atlanto-occipital dislocation. *Clin Nucl Med* 25:1031–1032
49. Jevitch V (1989) Traumatic lateral atlanto-occipital dislocation with spontaneous bony fusion: a case report. *Spine* 14:123–124
50. Jones DN, Knox AM, Sage MR (1990) Traumatic avulsion fracture of the occipital condyles and clivus with associated unilateral atlanto-occipital distraction. *AJNR* 11:1181–1183
51. Junge A, Krueger A, Petermann J, Gotzen L (2001) Posterior atlanto-occipital dislocation and discoligamentous C3–C4 instability with survival. *Spine* 26:1722–1725
52. Kaufmann RA, Dunbar JS, Botsford JA, McLaurin RL (1982) Traumatic longitudinal atlanto-occipital distraction injuries in children. *AJNR* 3:415–419
53. Kaufmann RA, Carroll CD, Buncher CR (1987) Atlanto-occipital junction: standards for measurement in normal children. *AJNR* 8:995–999
54. Kenter K, Worley G, Griffin T, Fitch RD (2001) Pediatric traumatic atlanto-occipital dislocation: five cases and a review. *J Pediatr Orthop* 21:585–589
55. Kohler H, Vock B, Hochstein P, Wentzensen A (1998) Die Fusion des craniocervicalen Übergangs mit dem “Cervifix” nach überlebter atlanto-occipitaler Dislokation. *Chirurg* 69:677–681
56. Labbe JL, Leclair O, Duparc B (2001) Traumatic atlanto-occipital dislocation with survival in children. *J Pediatr Orthop B* 10:319–327
57. Lee C, Woodring JH, Goldstein SJ, Daniel TL, Young AB, Tibbs PA (1987) Evaluation of traumatic atlanto-occipital dislocation. *AJNR* 8: 19–26
58. Lee C, Woodring JH, Walsh JW (1991) Carotid and vertebral artery injury in survivors of atlanto-occipital dislocation: case reports and literature review. *J Trauma* 31:401–407
59. Levine AM, Edwards CC (1989) Traumatic lesions of the occipitoatlantoaxial complex. *Clin Orthop* 239:53–68
60. Matava MJ, Whitesides TE, Davis PC (1993) Traumatic atlanto-occipital dislocation with survival: serial computerized tomography as an aid to diagnosis and reduction. A report of three cases. *Spine* 18:1897–1903
61. Maves CK, Souza A, Prenger EC, Kirks DR (1991) Traumatic atlanto-occipital disruption in children. *Pediatr Radiol* 21:504–507
62. Montane I, Eismont FJ, Green BA (1991) Traumatic occipitoatlantal dislocation. *Spine* 16:112–116
63. Naso WB, Cure J, Cuddy BG (1997) Retropharyngeal pseudomeningocele after atlanto-occipital dislocation: report of two cases. *Neurosurgery* 40: 1288–1290
64. Nichols J, West JS (1994) Traumatic atlanto-occipital dislocation injury in children. *AORN J* 60:544–554
65. Nischal K, Chumas P, Sparrow O (1993) Prolonged survival after atlanto-occipital dislocation: two case reports and review. *Br J Neurosurg* 7: 677–682
66. Page CP, Story JL, Wissinger JP, Branch CL (1973) Traumatic atlanto-occipital dislocation: case report. *J Neurosurg* 39:394–397
67. Palmer MT, Turney SZ (1994) Tracheal rupture and atlanto-occipital dislocation: case report. *J Trauma* 37: 314–317
68. Pang D, Wildberger JE Jr (1980) Traumatic atlanto-occipital dislocation with survival: case report and review. *Neurosurgery* 7:503–508
69. Papadopoulos SM, Dickmann CA, Sonntag VKH, Reke HL, Spetzler RF (1991) Traumatic atlanto-occipital dislocation with survival. *Neurosurgery* 28:574–579
70. Park JB, Ha KY, Chang H (2001) Traumatic posterior atlanto-occipital dislocation with Jefferson fracture and fracture/dislocation of C6–C7: a case report with survival. *Eur Spine J* 10: 524–528
71. Partrick DA, Bensard DD, Moore EE, Calkins CM, Karrer FM (2000) Cervical spine trauma in injured child: a tragic injury with potential for salvageable functional outcome. *J Pediatr Surg* 35:1571–1575
72. Patel JC, Tepas JJ III, Mollitt DL, Pieper P (2001) Pediatric cervical spine injuries: defining the disease. *J Pediatr Surg* 36:373–376
73. Powers B, Miller MD, Kramer RS, Martinez S, Gehweiler JA (1979) Traumatic anterior atlanto-occipital dislocation. *Neurosurgery* 4:12–17
74. Przybylski GJ, Clyde BL, Fitz CR (1996) Craniocervical junction subarachnoid hemorrhage associated with atlanto-occipital dislocation. *Spine* 21: 1761–1768
75. Putnam WE, Stratton FT, Rohr RJ, Stitzell W, Roat G (1986) Traumatic atlanto-occipital dislocation: value of the Powers ratio in diagnosis. *J Am Osteopath Assoc* 86:798–804

76. Ramsay AH, Waxman BP, O'Brien JF (1986) A case of traumatic atlanto-occipital dislocation with survival. *Injury* 17:412–413
77. Rockswold GL, Seljeskog EL (1979) Traumatic atlantocranial dislocation with survival. *Minn Med* 62:151–154
78. Roy-Camille R, Benazet JP, Saillant G, Henry P, Mamoudy P, Leonard P (1986) Luxation traumatique occipitoatlantienne. Interet de nouveaux signes radiologiques (a propos de deux cas). *Rev Chir Orthop* 72:303–309
79. Saeheng S, Phuenpathom N (2001) Traumatic occipitoatlantal dislocation. *Surg Neurol* 55:35–40
80. Shamoun JM, Riddick L, Powell RW (1999) Atlanto-occipital subluxation/dislocation: a "survivable" injury in children. *Am Surg* 65:317–320
81. Shirakawa K, Iwanaga M, Baba H, Yonekura M, Teramoto S, Iwamoto K (1996) Traumatic atlanto-occipital dislocation: a case report with survival. *No Shinkei Geka* 24:451–454
82. Sponseller PD, Cass JR (1997) Atlanto-occipital fusion for dislocation in children with neurologic preservation. *Spine* 22:344–347
83. Steinmetz MP, Verres M, Anderson JS, Lechner RM (2002) Dual-strap augmentation of halo orthosis in the treatment of atlanto-occipital dislocation in infants and young children. *J Neurosurg* 96:346–349
84. Sun PP, Poffenbarger GJ, Durham S, Zimmerman RA (2000) Spectrum of occipitoatlantoaxial injury in young children. *J Neurosurg* 93:28–39
85. Takayasu M, Hara M, Suzuki Y, Yoshida J (1999) Treatment of traumatic atlanto-occipital dislocation in chronic phase. *Neurosurg Rev* 22:135–137
86. Tepper SL, Fligner CL, Reay DT (1990) Atlanto-occipital disarticulation: accident characteristics. *Am J Forensic Med Pathol* 11:193–197
87. Tomasini A, Berlot G, Randino A, Viviani M (2002) Atlanto-occipital traumatic dislocation. *Am J Emerg Med* 20:133–135
88. Traynelis VC, Marano GD, Dunker RO, Kaufmann HH (1986) Traumatic atlanto-occipital dislocation: case report. *J Neurosurg* 65:863–870
89. Vedantam R, Crawford AH (1997) Multiple noncontiguous injuries of the spine in child: atlanto-occipital dislocation and seat-belt injury of the lumbar spine. *Acta Orthop Belg* 63:23–27
90. Watridge CB, Orrison WW, Arnold H, Woods GA (1985) Lateral atlanto-occipital dislocation: case report. *Neurosurgery* 17:345–347
91. Watteau N, Roger R, Besson M, Roulot B, Alison D (2001) Traumatic atlanto-occipital dislocation with regressive tetraparesia. *J Radiol* 82:1005–1007
92. Werne S (1957) Studies in spontaneous atlas dislocation. *Acta Orthop Scand (Suppl)* 23:1
93. Woodring JH, Selke AC, Duff DE (1981) Traumatic atlanto-occipital dislocation with survival. *AJR* 137:21–24
94. Yamaguchi N, Ikeda K, Ishise J, Yamashita J (1996) Traumatic atlanto-occipital dislocation with long-term survival. *Neurol Med Chir* 36:36–39
95. Zampella EJ, Duvall ER, Langford KH (1988) Computed tomography and magnetic resonance imaging in traumatic locked-in syndrome. *Neurosurgery* 22:591–593
96. Zigler JE, Waters RL, Nelson RW, Capen DA, Perry J (1986) Occipito-cervico-thoracic spine fusion in a patient with occipito-cervical dislocation and survival. *Spine* 11:645–646
97. Zilch H (1977) Traumatische atlanto-occipitale Verrenkung. *Chirurg* 48:417–421
98. Zivot U, Di Maio VJ (1993) Motor vehicle-pedestrian accidents in adults: relationship between impact speed, injuries and distance thrown. *Am J Forensic Med Pathol* 14:185–186